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Assessing the Environmental Impact of Gas Condensate Leakage on Soil in Asalouyeh: An Investigation

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ABSTRACT

In this study, the concentration of total petroleum hydrocarbon (TPH) remaining in the sediments of Asaluyeh (a city in Fars province) that were polluted in the fall of 2021 due to gas condensate leakage was investigated. After the accident, soil from deeper layers was mixed with surface soil and rain washed some of the pollution deeper into the soil. Five months after these operations, the TPH level of the soil was measured. The results showed that the concentration of soil pollution in the study area was 356.5 µg/g, which corresponds to the lower end of the moderate pollution range.

1. Introduction

Oil pollution is a significant environmental hazard that can result from various human activities. Leakage of petroleum products and gas condensate from pipelines is one such environmental problem that can cause soil pollution and subsequent contamination of underground water, leading to pollution of water resources. Petrochemical accidents can also cause death or migration of organisms exposed to pollution, changes and reduction of biodiversity, and alterations in the behavior of organisms in the affected region's environment [1].

Total petroleum hydrocarbons (TPH) comprise aliphatic and polycyclic aromatic compounds (PAH), including 16 toxic and carcinogenic polycyclic aromatic compounds such as naphthalene, sphentylene, anthracene, fluorene, fluoranthene, phenathrene, benzo[a]pyrene, benzo[k]fluoranthene, among others, as identified by the United States Environmental Protection Agency. Typically, after accidents, volatile oil compounds such as benzene and toluene, which are highly toxic, evaporate quickly, leaving behind heavier petroleum compounds that can persist in the

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environment, polluting soil and water bodies, including oceans and beaches. However, these compounds can gradually break down through processes such as emulsification, oxidation, and biological decomposition by microorganisms such as Alcanivorax and Cycloclasticus [2]. When volatile substances evaporate rapidly and other petroleum compounds are gradually broken down, the resulting toxic substances can be inhaled and stored in the body's fat tissues, particularly in the liver, kidney, spleen, and adrenal gland. The type and severity of health effects caused by polycyclic aromatic hydrocarbons (PAHs) depend on factors such as the concentration of the substances, the duration of exposure, the route of exposure, and the individual's response to them. The short-term effects of exposure are not clear, but long-term exposure to these compounds can cause cataracts, liver and kidney damage, and jaundice. For example, continuous skin contact with naphthalene can cause skin redness and inflammation, while inhalation or ingestion of large amounts of naphthalene can destroy red blood cells. One of the most significant effects of these compounds, particularly the 16 toxic aromatic compounds, is their mutagenic and carcinogenic potential, with benzo[a]pyrene being a particularly notorious carcinogen.

Several methods have been proposed for removing oil pollution from the environment, including manual collection, physical collection, use of absorbents, burning, and biological decomposition.

The Persian Gulf is an enclosed sea located between the Iranian and Arabian peninsulas, along the Oman Sea in the Indian Ocean. Its warm climate, which can exceed 50°C, supports a unique biological fertility and sensitive habitat for living resources. However, the Persian Gulf is vulnerable to oil and gas pollution resulting from drilling, exploitation, and accidents due to its vast oil and gas reserves.

During a gas condensate leak from pipes located 2 meters underground, two areas in Asaluyeh (a city in Fars province) were contaminated in mid-autumn of 2021: the first area covered 1400 square meters to a depth of 1.5 meters (2100 cubic meters of soil), while the second area covered 300 square meters to a depth of 2 meters (600 cubic meters of soil). In the initial investigations, the concentrations of benzene and toluene in the first area were found to be 0.25 and 0.15 ppm, respectively, while in the second area they were 0.15 and 0.1 ppm, respectively.



Fig. 1. Leakage of gas condensate

Initially, several methods were proposed to remediate the contaminated soil, including aeration, washing, and biological decomposition using microorganisms that break down petroleum substances. During the investigation period, some of the oil materials were transported to deeper soil layers due to rainfall. Ultimately, the method of aerating and mixing the soil from deeper layers to the surface was used to reduce the pollution load.



Fig. 2. The lightening processes

2. Research method

To assess the remaining oil pollution in the area, soil samples were collected in March 2021. At the time of the accident, the average temperature in the environment was 24°C, and it was anticipated that some of the pollution would have dissipated from the soil due to evaporation, washing, aeration, and natural biological decomposition after several months. The objective of this study was to measure the total petroleum substances in the soil of the region five months after the accident and to investigate the effects of evaporation, aeration, rain washing, and natural biological decomposition.

For this purpose, 12 surface soil samples were collected from the contaminated area using a steel shovel and transferred to pre-washed and contamination-free aluminum containers, which were then sent to the laboratory for analysis. The samples were completely dried in a freeze dryer within 6 hours, and extraction was performed using the US-EPA method SW846 method 3550 with either sonic or shaker equipment. The precipitate was mixed with Na_2SO_4 and transferred to a 250 ml glass or Teflon container. Surrogate standards were added to each container, followed by the addition of 100 ml of a 1:1 dichloromethane/acetone mixture. The samples were sonicated for 3 minutes, and the solvent was extracted. The solvents were combined in a clean flask, and the extraction process was repeated two more times. The extracted material was filtered through glass wool and dehydrated using sodium sulfate. The volume of extracted material was reduced, with the amount of sodium sulfate used in the blank or control sample being similar to that used in the other samples. The total oil compounds were measured using GC-MS.

3. Results and analysis

Table 1 contains the relevant data on the average oil compounds of total TPH.

Table 1. Average concentration of different petroleum compounds

Type	µg/g	Type	µg/g	Type	µg/g	Type	µg/g
C10	69.54	Pristane C19	9.33	C24	2.62	C32	0.06
C11	51.94	C18	12.50	C25	2.76	C33	0.04
C12	41.62	Phytane C20	9.39	C26	1.62	C34	0.02
C13	19.68	C19	11.65	C27	1.33	C35	0.01
C14	29.07	C20	9.10	C28	1.30	C36	0.01
C15	25.84	C21	7.00	C29	0.73	C37	0.00
C16	20.04	C22	4.98	C30	0.37	C38	0.00
C17	19.79	C23	3.96	C31	0.16	C39	0.00

The results of this investigation showed that the average concentration of petroleum compounds in soil samples collected from the contaminated area after 5 months of remediation was 356.5µg/g. In order to assess the level of oil pollution in the area, the classification system proposed by Commendatore et al. [3] was used, which divides areas into three categories based on the petroleum compound concentration: low pollution (10µg/g), low to medium pollution (10-100µg/g), and medium to high pollution (100-1000 µg/g). Additionally, Readman et al. [4] suggested that a concentration of 100 µg/g indicates high contamination of total hydrocarbons in sediments, while Tolosa et al. [5], based on the studies of Volkman et al. [6], considered concentrations above 500 µg/g as severe contamination and concentrations below 10 µg/g as uncontaminated.

Based on these classification systems, the remaining pollution in the investigated area after 5 months of remediation fell within the low range of moderate to high pollution.

Several studies have investigated the concentration of TPH in sediments across the Persian Gulf region. Agah et al. [7] reported an average TPH concentration of 115.5 µg/g in sediments from Genaveh port (located 40 km before Behrgan port), while Hatami et al. [8] found TPH levels ranging from 117 to 138 µg/g in sediments from the Behrgan area. Panbezadeh [9] reported TPH concentrations of 63-750 µg/g in sediments from Bandar Abbas.

Tolosa et al. [10] measured TPH concentrations in sediments from the United Arab Emirates, Qatar, Bahrain, and Oman, finding concentrations ranging from 100-16,400, 2,200-84,000, 16,600-779,000, and 10-7,600µg/kg, respectively. Al Darvish et al. [11] reported an average TPH concentration of 12,253µg/g in beaches located in Dubai and the United Arab Emirates, while De Mora et al. [12] measured TPH concentrations of 2-724µg/g in beaches located in Bahrain, Kuwait, and Saudi Arabia.

Tolosa et al. [5], in their comprehensive studies, found TPH concentrations in beaches located in Qatar to range from 779 to 16µg/g, in sediments from the United Arab Emirates to range from 0.1 to 416µg/g, and in sediments collected near the Bahrain oil refinery run by BAPCO to be 779µg/g (in the relatively contaminated range) [6], [13].

4. Conclusion

Although the level of soil pollution in the investigated area fell within the low range of moderate pollution concentrations, it was comparable to sediments found along the southern shores of the Persian Gulf, which are exposed to continuous natural and human pollution from petroleum compounds. To reduce the amount of pollution in soils contaminated by oil accidents, it is necessary to use and compare different remediation methods, including physical methods.

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